

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of

Roger HANSEN

Serial No. 10/530,355

Filed December 30, 2005

MONITORING SYSTEM  
AND DEVICE FOR AN ELECTRIC  
POWER LINE NETWORK



: **Mail Stop: ISSUE FEE**

: **Confirmation No. 7768**

: [Group Art Unit 2612]

: Examiner George A. Bugg]

: Attorney Docket No. 2005\_0606A

**RESPONSE TO ALLOWANCE**

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Sir:

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Respectfully submitted,

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09-17-2007	1449	List of References cited by applicant as considered by examiner
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09-17-2007	BIB	Bibliographic Data Sheet
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08-24-2007	SRNT	Examiner's search strategy and results
02-23-2006	M903	Notice of DO/EO Acceptance Mailed
12-30-2005	LET	Miscellaneous Incoming Letter
12-30-2005	136A	Authorization for Extension of Time all replies
12-30-2005	OATH	Oath or Declaration filed
12-30-2005	BIB	Bibliographic Data Sheet
11-02-2005	M905	Notice of DO/EO Missing Requirements Mailed
08-08-2005	IDS	Information Disclosure Statement (IDS) Filed
08-08-2005	FOR	Foreign Reference
08-08-2005	NPL	NPL Documents
04-06-2005	TRNA	Transmittal of New Application
04-06-2005	136A	Authorization for Extension of Time all replies
04-06-2005	SPEC	Specification
04-06-2005	CLM	Claims
04-06-2005	ABST	Abstract

04-06-2005	DRW	<a href="#">Drawings</a>
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04-06-2005	WFEE	<a href="#">Fee Worksheet (PTO-06)</a>
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Ref. 110972/AF/OMK  
16. januar 2006

Patent application No. NO 2002 4833

Applicant: Protura AS

Title: "A device for monitoring an electric overhead line"

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The present invention relates to a device for monitoring an electric overhead transmission line.

5 Power lines for transmission of electric power are dimensioned for the amperage to be transmitted, and for the length of the line spans in question. In addition, due consideration must be taken with regard to exposing the line span to wind, as well as the weighing down by snow and ice in northern areas.

10 It is a general physical fact that electric current flowing through a line will heat the line, and the degree of heating is connected with the amperage. Overheating leads to an expansion of the metal in the power line, and as a consequence of this, the power line will experience a sag increase, which means that the safety distance sag to ground level is decreased. In certain cases, strong heating for instance due to a large amperage, may give a situation where it is unsafe to stay underneath the power line.

15 In the warm season, and particularly in warm world regions, the power lines may become strongly heated by the sun and by a generally high air temperature, and if currents are then transmitted with amperages approaching the maximum amperage for which the line is designed, the wire may experience such a large sag increase that it will be perilous to enter the area thereunder. Also in other areas the increase of sag for the power lines in summer, may cause that the safety distance to trees thereunder will be too short. This may cause a flashover from the power line to the trees, and may result in a forest fire.

25 In other words, the power network companies may experience the problem that it is difficult to transmit the energy amount that the power line was actually constructed for.

30 In areas where power is delivered from nuclear power plants and thermal power plants, which plants have a laborious and slow manner of regulating the power production, the consequence is that it is difficult to transmit a high amount of energy just when the need is at the greatest. This leads again to the consequence that power suppliers and energy companies lose large amounts of money every year.

35 The power suppliers have no commercially accessible solutions for surveillance of the line network with regard to avoiding the above mentioned problems. Hence, a power supplier may be under the delusion that the energy transmission takes place in accordance with statutory safety routines and with the necessary safety margins,

but has in reality no control over ambient temperature, solar heating etc. that in reality will determine the transmission capacity of the line.

5 The problem can be solved by building more power lines and stronger power lines, which may give a possibility to increase the safety margins, but this is a rather lengthy and costly process, and in addition, it is difficult to get a concession for new line profiles. Therefore, this solution is not of interest in most cases.

10 One is aware that a system has been developed for determining the temperature in a power line through measuring air temperature, and considering possible cooling effect of wind or rain. Thereby it is supposedly possible to calculate the amount of energy that can be transmitted at any time without any danger of overload. This calculating method has been taken in use in many countries, and provides a tool for the power plants for determining transmission capacity hour by hour. The method is  
15 based on weather forecasting and mathematical treatment of expected meteorological data in areas where the power lines are situated. As everybody knows, meteorological data are more or less reliable. The method has, naturally, turned out not to be sufficiently reliable with regard to the needs of the power companies.

20 Consequently, the fact that the power suppliers lack an option for genuine surveillance of the power lines, remains as a specific problem, since no commercially available solutions exist for making real-time measurements on such lines.

25 The present invention aims at solving the above mentioned problem, and the solution comes in the form of a device for monitoring an electric overhead line, wherein the device of the invention is characterized by being an independently working real-time multisensor to be mounted in a position on a line span, and with a built-in transmitter for transmitting sensor signals to a remote central.

30 The multisensor comprises in a basic embodiment, a slope gauge and temperature sensors for line temperature and air temperature. Further, the multisensor may comprise at least one additional sensor for recording at least one parameter in a group of parameters comprising slope, increased line sag, galloping, visual image of  
35 the line, wind speed, wind direction, distance to ground level, snow and ice load as well as quality/stability of line current. These sensors may come from a group of sensors comprising bimetallic temperature probes, mercury slope switches, ball relay slope switches, camera, wind gauge, laser range finder and a metering transformer.

The temperature probes for air temperature and line temperature may be connected to the camera, for visual rendering of temperatures in a section of a visual inspection image recorded by the camera.

- 5 The multisensor may be equipped with circuitry for providing a trigger function for transmitting an alarm signal when pre-set threshold values for temperature or other of the above mentioned parameters, are exceeded.

- 10 In a favourable embodiment, the multisensor comprises a current transformer for fetching operating power from the overhead line itself.

Alternatively, the multisensor may comprise a system of solar cells and battery for providing operating power.

- 15 The multisensor, or a part thereof, may be shaped as two semi-cylinders hinged to each other, for mounting by folding the semi-cylinders together round the line.

The outer surface of the device may be equipped with visible information/advertising.

- 20 The multisensor may comprise a receiver for control signals from the remote central.

The transmitter may favourably be a radio transmitter.

- 25 Additionally, the transmitter may be connected to the power line itself, in order to use the power line as a transmission medium to the central.

- 30 Hence, the present invention provides the possibility of real-time regulating of maximum transferable power, since it will be possible to monitor continuously from a power plant the condition of the power lines in question, so that overload, forest fire and dangerous passage of persons can be avoided, while at the same time the capacity of the lines can be utilized at a maximum.

In the following, the invention shall be described more closely by going through some detailed embodiments, and with reference to the appended drawings, where

- 35 Fig. 1 shows an embodiment of a device in accordance with the invention, mounted on an overhead line, and with an outer casing that is transparent for illustration purposes,



Fig. 2 shows an alternative embodiment of the device in accordance with the invention, having a "split" construction, and

Fig. 3 shows an example of an image from a camera that may be included in the device in accordance with the invention.

5

As mentioned above, the invention consists in a device that can be designated as a "multisensor" that is able to detect, and output signals regarding, a plurality of parameters that are of importance for power lines. In a particular case, it is not necessarily important to monitor all parameters, but some of the parameters

10 mentioned here, will always be of interest: it concerns line temperature, which is measured by a probe that engages the line itself, air temperature to be measured by a probe directed outward into the air, line slope or line sag increase, galloping, wind speed, wind direction, distance to ground level, quality of line current, snow/ice load on the line, and a visual image of the line.

15

Increase of line sag ("sagging") is measured by detecting a slope angle, for instance by means of mercury switches. Sag increase can be due to various factors, such as previously mentioned. If the sag increase measurement is set in connection with a temperature measurement, snow and ice load can be determined. The quality and  
20 stability of current flowing in the line can be measured by means of a measurement transformer, while wind speed and wind direction are measured by means of a traditional wind gauge. The distance to ground level is measured separately by means of a built-in laser range finder.

25 In addition, the multisensor may include "visual safety backup" by having mounted therein a camera that can be used to see visually the various warning signals. Besides, the camera has an independent function for monitoring the line itself, weather conditions around the line and vegetation below the line.

30 Warning regarding "galloping line" has been mentioned above, and this means a warning regarding a damaging phenomenon for a line, namely a vibration mode in which a waveform propagates along the line, usually started by wind. A propagating wave, or for that matter a standing wave, along the line may have amplitudes large enough to result in damage. It is therefore important to detect such a motion, i.e.  
35 receiving an automatic warning regarding such a motion from a sensor device in accordance with the invention, because then the current can be shut down before destruction occurs, and the damage can then be limited.

As regards automatic warning signals, so-called "critical" sag can be mentioned, which means that the sag increases beyond a previously set criterion. When this situation is signalled as an automatic warning from the sensor device in accordance with the invention, the amperage can be reduced if the increased sag is due to heat in the line. Or some action can be started to remove possible snow/ice load from the line span if weighing down should be the cause of the exaggerated sagging.

It is referred to fig. 1, where a preferable embodiment of a device in accordance with the invention appears, mounted on an overhead line. For illustrative purposes, the outer casing is transparent.

The device is attached tightly to the high voltage line and surrounding the line. Inside a weather-proof outer casing, made for instance of a strong plastic material, there are instruments of the above mentioned types: a camera is arranged so as to peer out through a window with a field of view along the line and preferably below the line. A transformer is arranged to collect operating power from the very current through the line, and in connection with this power transformer there is also a measurement transformer for checking the stability and quality of the line current. In a separate box, sensors/signal generators are arranged for sag measurement, in the form of mercury switches. In the same generator box there is also circuitry for generating signals regarding temperature in the line and the surrounding air, respectively, and these signals are generated on the basis of measurement signals from temperature probes engaging the line itself, and outside the outer casing.

In the shown embodiment, the multisensor device also contains a log for recording measurements, as well as a communication unit, which unit is, in the preferred embodiment, able to perform two-way communication. This means that the unit, in addition to transmitting radio frequency signals to a remote central, is also capable of receiving control signals from the same central.

The preferred embodiment also comprises a wind gauge, which is not visible in the drawing. The wind gauge operates of course in connection with an opening in the outer casing. A laser range finder is incorporated in the signal generator box, and measures the distance to the terrain below, through a window in the outer casing.

For the rest, the outer casing comprises, in the preferred embodiment of the device, space for outside information or advertisement.

In fig. 2 appears an alternative embodiment of the device in accordance with the invention. In this embodiment it appears that a central section that contains a current transformer for fetching operating power from the magnetic field of the power line, is divided in two so as to make the installation on the power line simple and rapid. The two box-like units on the sides contain single sensors of the above mentioned types, there is for instance an opening shown in the front left side for an internal camera, and in addition there is communication equipment and a possible logging means.

In fig. 3 appears an image recorded by a camera built into a device in accordance with the invention, which image shows the situation around the line such as it would appear visually, and in addition a bar has been laid in at the top of the picture, to show the temperatures of the air and of the line. Such an image can be transmitted as a radio signal.

As previously mentioned, the device in accordance with the invention constitutes a multisensor, which means that the device is able to measure a number of different parameters, but the device can also be specially adapted to deal with fewer parameters, or possibly more parameters, depending on the conditions in the actual location. What is regarded as minimum equipment in the sensor, are a slope gauge and temperature probes for air and line temperatures. The slope gauge, preferably in the form of a mercury switch or relay with a ball (ball relay), provides information regarding sag, namely when the slope angle changes and becomes steeper, and the temperature probes provide information regarding the reason for the possible sag increase, namely either overheating of the line, or ice/snow load at low temperatures. The temperature probes are preferably bimetallic temperature probes.

The remaining sensor types that have been mentioned, are optional. Transmission equipment is obligatory, but receiver equipment for receiving control signals, should preferably be included also.

A simple design of the multisensor can work in the following exemplary manner: bimetallic temperature probes are connected in series with slope angle gauges, for instance in the form of mercury switches. The mercury switches operate by forming contact, or breaking contact, depending on the inclination of the switch. Thus, the mercury switches are mounted in the multisensor with adjustment screws so that a default angle can be adjusted, and then in such a manner that contact is formed or broken for a certain angle of inclination. In other words, with this type of slope gauge it is detected only whether the angle of inclination is above or below a certain limit

angle. However, several such gauges can be mounted if it is desirable to have detection ranges of finer graduation.

Since the multisensor in accordance with the invention shall always measure the slope of the line, the sensor must be mounted at a proper distance from the mid-point of a span, because at mid-point the slope will normally be equal to 0, no matter how much the sag is increased. This means that the sensor can advantageously be mounted in an area midway between a pylon and the mid-point of the span, or possibly even closer to the pylon.

One or several mercury switches/slope gauges for detecting change in sag, were mentioned above. In a practical case, the preferable number could be two such gauges, namely one regarding "50%" of a critical value, and one further mercury switch for the critical value itself.

In order to distinguish between cases of increased sag for the line caused by snow loads and caused by high line temperature, functions have been built in to set threshold values for line temperature in beforehand. If the line sags to a detection value, and the line temperature is for instance lower than a certain pre-set temperature threshold value, the sensor will provide a signal indicating snow/ice load. On the other side, the sensor will be able to provide a signal regarding increased sag due to exaggerated heat in the line, if a line temperature is detected that is higher than a pre-set threshold value. Hence, it is realized that the sensor in such a case transmits a signal of interest based on two conditions detected at the same time.

With the camera mounted in the sensor device, it will possible to verify the signal in question, via the camera.

Also a signal regarding a galloping line is obtained on the basis of the same technical solution, using for example a mercury switch as a slope gauge, but then a mercury switch which is turned 180° relative to the above mentioned mercury switches. Thus, the galloping detector responds to an inverse slope of the line, which is typical for the galloping phenomenon. Since this phenomenon is of a rapid and transient type, measures are preferably made to avoid that a galloping signal arises and disappears in step with the galloping. Therefore, a relay is mounted and set for a desired, timed hold contact, or the signal must be signed out. Hence, greater security is obtained regarding detecting an incoming galloping signal in the central.

Besides, galloping may occur in two perpendicular planes, namely mostly in the plane spanned by the line span itself, which is a vertical plane, but the oscillations may also occur in a horizontal plane. Experiments show that galloping in both planes can be detected by means of one and the same mercury switch.

5

As extra equipment, there may be mounted a laser range finder which checks continuously the distance from the line to the ground level, and consequently the remaining signals regarding line deviations, i.e. increased sag and possible galloping, can be verified.

10

To ensure that the previously mentioned sensors work properly, it is important that the multisensor does not twist around the line. The sensor should therefore be attached firmly from the start, but in addition, if the line itself is exposed to twisting movements about its axis, the sensor could be equipped with a cylindrically rotatable suspension to ensure that the multisensor stays at rest relative to a vertical plane, i.e. that it does not rotate relative to the surroundings.

15

It is a separate point regarding the multisensor, that different measuring methods used at the same time, in collection will provide a reliable result. In the embodiment where a current transformer is used to provide energy from the power line itself, there will be no particular limitations regarding the energy demand of the sensor. In another embodiment adapted for power lines that do not transmit high voltage power, it is possible to use the actual current from two phase leads running in parallel next to the sensor device, in such a manner that the very current in the lines is used for powering the sensor. In another embodiment, for example adapted to telecommunications lines, power current can be supplied separately via the nearest pylon carrying power current.

20

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The sensor device preferably has transmitter modules for every signal to be transmitted. Preferably, it also contains a receiver system, so that it will be possible to activate the camera for visual inspection, or to activate other single sensors in order to double-check signals that have been received in the central. All signals are transmitted via the power company's own data system, which system is based on for instance the RTU system, possibly the Scada system, or using RF signals. All signals are logged. The central receives the signals and can make decisions regarding transmission of more or less power through the lines where the sensor devices are mounted. Because the sensor devices transmit signals to the central, where the signals are logged, it is possible to implement measures prior to a possible

30

35

breakdown. As an example, it can be mentioned that if the control room receives a signal to the effect that a line span is galloping, this provides an opportunity to load power over to another power line before the first one breaks down, and in such a manner it will be possible to avoid power shut-off for some areas.

5

Further, the logging of the signals will provide a possibility for preparing trends and statistics for the various power lines where the system is mounted, so that it will be possible to have documented statistics based on real time measurements.

- 10 Since the system of the invention is based on real time measurements on the lines, the decisions that are made in the central on the basis of the sensor signals, will always be correct.

- 15 Regarding information/advertising on the outside of the multisensor outer casing, the pricing of the power company may appear there, or possibly the power amount that is transmitted through the line. Such an information device could of course be developed further to be able to display variable information, particularly in a context as previously mentioned, where operating power can be taken from the line itself. In such a case, operating a variable display is no problem. This may be of special  
20 interest for instance where power lines cross communication arteries like for instance roads or canals.

## CLAIMS

1. A device for monitoring an electric overhead line,  
5 characterized in that said device is an independently operating real-time multisensor to be mounted in a position on a line span, and with a built-in transmitter for transmitting sensor signals to a remote central.
2. The device of claim 1,  
10 characterized in that said multisensor comprises an inclination angle sensor and temperature sensors for line temperature and air temperature.
3. The device of claim 2,  
characterized by at least one further sensor for recording at least one  
15 parameter in a parameter group that comprises angle of inclination, line sag increase, galloping, visual image of the line, wind speed, wind direction, distance to ground level, snow and ice load as well as quality/stability of line current.
4. The device of claim 3,  
20 characterized in that the sensors belong to a sensor group that comprises bimetallic temperature probes, mercury inclination switches, ball relays, camera, wind gauge, laser range finder and a measuring transformer.
5. The device of claim 4,  
25 characterized in that temperature probes for air temperature and line temperature are connected to a camera for visual rendering of temperatures in a part of a visual inspection image recorded by the camera.
6. The device of claim 2 or 3,  
30 characterized in that the multisensor is equipped with circuitry for providing a trigger function for transmitting an alarm signal when pre-set threshold values of temperature or others among said parameters are exceeded.
7. The device of claim 1,  
35 characterized in that the multisensor comprises a current transformer for fetching operating power from the overhead line itself.

8. The device of claim 1,  
characterized in that the multisensor comprises a system of solar cells  
and battery for providing operating power.
- 5 9. The device of claim 1,  
characterized in that the multisensor or a part thereof is shaped as two  
semi-cylinders hinged to each other, for mounting by folding the semi-cylinders  
together round the line.
- 10 10. The device of claim 1,  
characterized in that the outer surface thereof is equipped with visible  
information/advertising.
11. The device of claim 1,  
15 characterized in that the multisensor comprises a receiver for control  
signals from the central.
12. The device of claim 1,  
characterized in that the transmitter is a radio transmitter.
- 20 13. The device of claim 1,  
characterized in that the transmitter is connected to the power line  
itself, in order to use the power line as a transmission medium to the central.



**ABSTRACT**

A device is provided for monitoring an electric overhead line, which device is constituted by an independently operating real time multisensor for mounting in a position on a span of the overhead line. The device has a built-in transmitter for transmitting sensor signals to a remote central.

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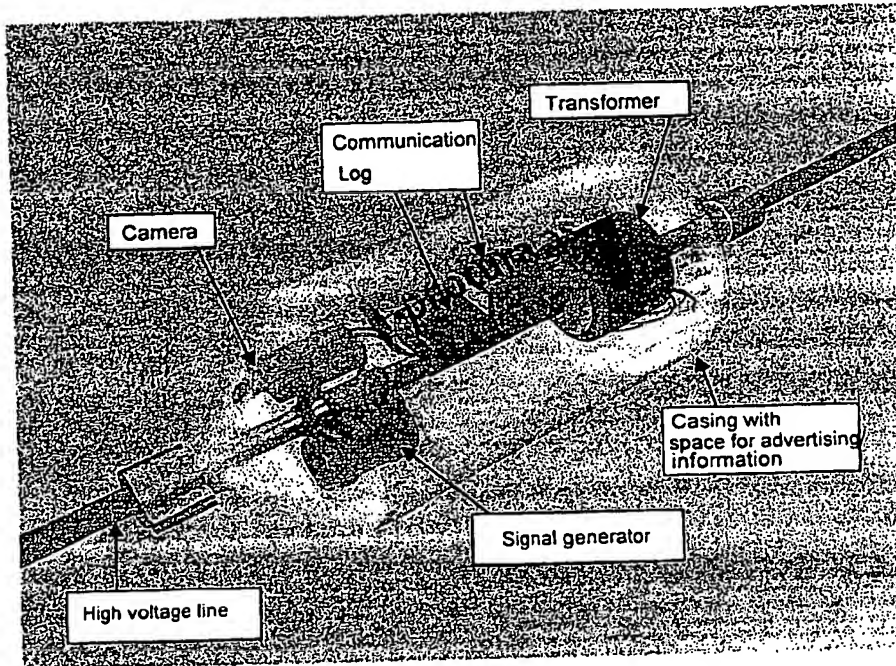


Fig. 1

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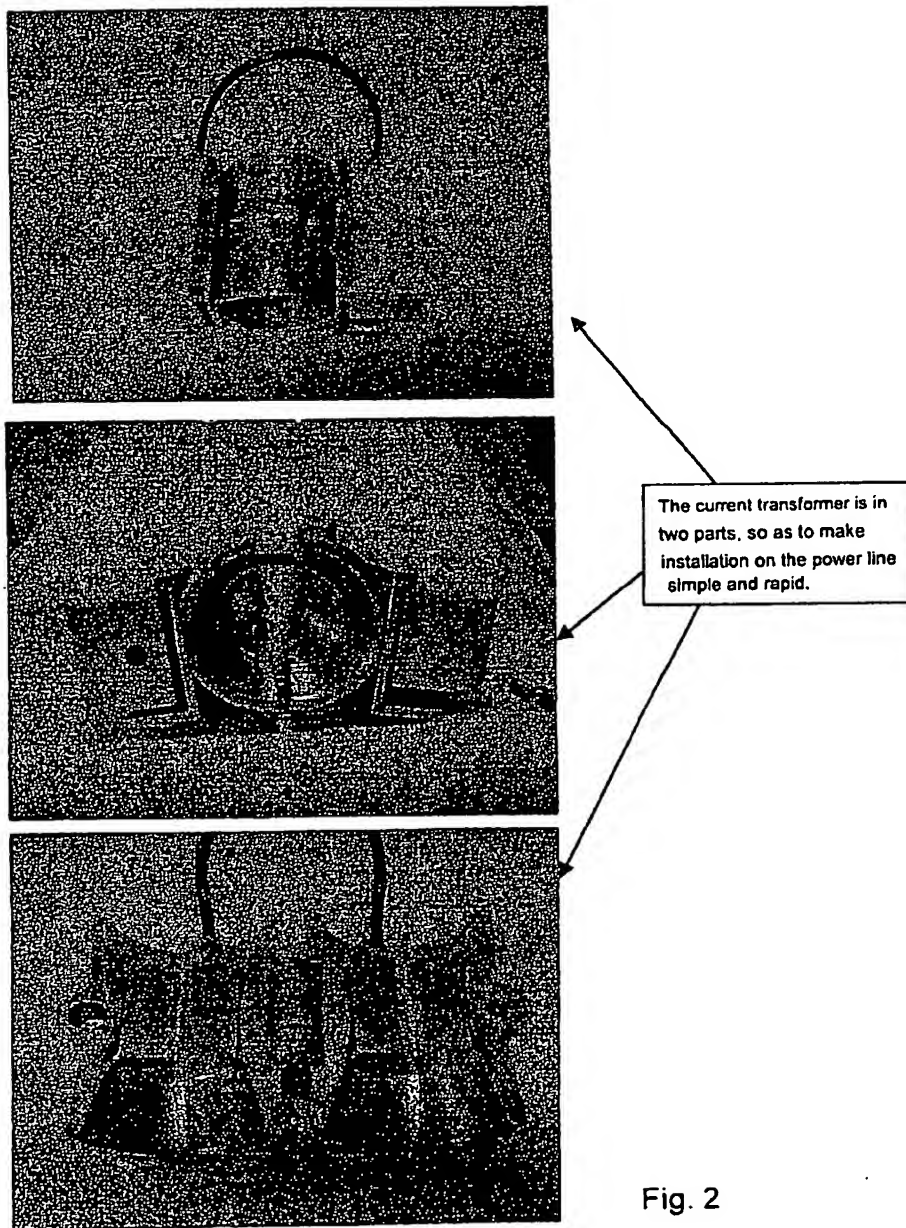


Fig. 2

BEST AVAILABLE COPY

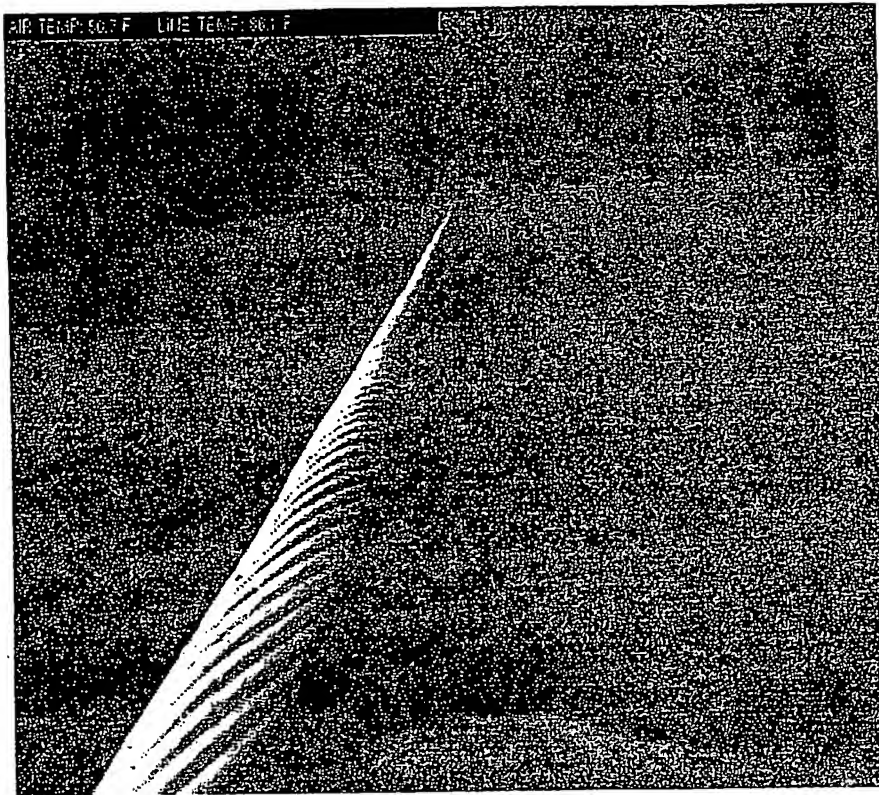


Fig. 3